Provision of a Distributed, Integrated ATM Displays for Global CNS System

Wide distribution of a Research Simulator

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Background

- The GCNSS project was carried out by a team led by Boeing to demonstrate a global System Wide Information Management
- In particular:
  - a proof of concept demonstration of advanced system architectures and CNS ATM
  - Dependent and independent aircraft position reporting
  - Satellite based communications both Ku and L band
  - Data fusion of radar and ADS data
- The demonstration was to show the capability to smoothly transition from radar controlled to ADS only environments

EARL GCNSS Requirement

- *To provide:*
  - *a DSR like display system that would show radar and ADS positions*
  - *Communications both Voice and CPDLC*
  - *The capability to accept live radar and ADS data*
  - *an overlay of simulated traffic*
- *The system to be widely distributed with displays:*
  - *At Boeing Mclean VA*
  - *At the Connexion by Boeing EOC Irvine CA*
  - *At Houston Air Traffic Control Center (ZHU)*
  - *In the Connexion by Boeing aircraft*

EARL Real Time Simulator

- *The EARL real time simulator is based on an expansible network centric object oriented design*
- *The aircraft objects 'broadcast' ADS DO-242 messages on a 'VDL' channel*
- *The messages are broadcast internally using UDP Multicast – mirroring real world behavior*
- *Every function in the real time simulator follows the same broadcast concept*
- *The design allows for easy expansion and addition of sectors with minimal if any increase in system load*
- *For GCNSS this allowed addition of replicated control positions without any impact on system design*
- *All this based on use of existing IP protocols and capabilities*

Wide Distribution

- The wide distribution of the system was carried out over a star of T1 lines centered on Boeing McLean, that in theory would provide a 'virtual' LAN
- In practice there were protocol limitations that required some work
- The link to the Connexion by Boeing aircraft could not accept UDP-multicast
- Specific tunneling software was written by John Pesce to carry UDP multicast through the Connexion by Boeing comcen over the satellite links to the LAN in the Connexion by Boeing 737

Standard Internet Capabilities

- ***Each location and node had multicast capable routers***
- ***Multicast capable components on connection to the routers identify the multicast group IPs in which they are 'interested'***
- ***The routers between them build a tree of components that are interested in each multicast group***
- ***Multicast traffic destined for that group is received and forwarded to other reachable routers or components that are interested in that multicast group***
- ***Bandwidth is saved as messages are branched only when necessary and there is no requirement to repeatedly send the same message to several addresses on the same link***
- ***Where the routers are not capable as in the aircraft link, user configurable tunnels were used***

Data Inputs

- The real time simulator received surveillance data from the Surveillance Data Network (SDN)
- The SDN received the output from:
  - NAS radars feeding to Houston Center
  - ADS from Connexion by Boeing in Asterix Cat33 format
- Lincoln Laboratories collated and filtered the data and transmitted it to EARL on a secure T1 line
- The data was transmitted as CORBA objects carrying the beacon code as identity and flagged as being either a radar or ADS position
- The objects carried flight level/altitude and rate of vector change in 3 dimensions

Data Input Processing

- ***On receipt of an aircraft position***
  - ***If the aircraft did not exist in the simulator a new object was constructed***
  - ***Otherwise the aircraft object was sent a message updating its position***
- ***Aircraft objects in the real time simulation broadcast their positions every parameter number of seconds***
- ***ADS and Radar positions were received at differing rates***
  - ***ADS at ~ 1 per second***
  - ***Radar at ~ 1 per 7 – 10 seconds***

Aircraft Object Outputs

- *Live aircraft position updates were broadcast to the displays on receipt*
- *Simulated aircraft broadcast their positions at once every 6 seconds*
- *Position broadcasts were in DO-242 format with a flag indicating if it was radar or ADS*
- *From the point-of-view of the displays, there was no difference between live and simulated aircraft*

EARL Voice over IP – VOIP

- EARL developed VOIP to provide an extensible VHF emulation for simulation
- It provides high quality sound
- Controller to pseudo pilot voice communications
- Controller to Controller telephone communications
- The system is written in Java and runs on both Linux and Windows machines
- It was originally designed without bandwidth constraints in a closed LAN
- Since GCNSS CODECs have been added to reduce the bandwidth

EARL VOIP Capabilities

- *VOIP was modified to provide enhanced capabilities over a 'standard' VHF*
- *Step-On Prevention: VOIP prevents the 'two aircraft at once' problem by allowing the first aircraft to continue and muting all others*
- *Controller Precedence: A controller can break into any transmission and the controller transmission will mute all the aircraft connected to that sector. This can be necessary in a busy sector or when an aircraft has a 'stuck transmit switch'*
- *When an aircraft transmission is muted – the pilots are able to hear any unmuted transmissions but not hear feedback of themselves*

SATCOM

- *There were 2 communication satellite systems used:*
  - *Ku Geostationary with a large bandwidth*
  - *Iridium LEO low bandwidth designed for voice*
- *VOIP over Ku was carried as UDP multicast*
- *VOIP to Iridium went through an analogue bridge and Vox box as a transmit switch*
- *The analogue bridge took the input voice and output voice from a standard PC soundboard*
- *In the aircraft the transmission was speech over a normal Iridium phone call*

Voice Communications

- VOIP gave the capability for the control positions at Houston, McLean, and ERAU and all the pilot positions in the aircraft and the pseudo-pilots in ERAU to all hear and transmit to each other
- Informal testing by controllers at Houston Center showed that
  - there was no significant transmission delay with Ku band
  - The quality of Iridium and Ku were both far better than VHF

CPDLC

- *All the simulated aircraft objects are respond to and obey CPDLC commands*
- *GCNSS required flexible use of several 'standard' CPDLC: Miami Center, Builds 1,1a,2*
- *Decided to use a standalone easily configurable message system based on pull down menus*
- *Miami flavor CPDLC is a limited message set mainly for inbound aircraft with a pull down menu of pre-generated messages*
- *Messages when sent received a Logical Acknowledge from the receiving device*
- *The reply pull down menu only showed replies that were 'legal' to each initial message*
- *Free text and GI messages were added to allow flexibility*
- *The menus were very abbreviated e.g. MH – Maintain Heading*
- *When selected they were expanded e.g. Maintain Heading _ _ _*
- *The cursor would be positioned on the first field to be completed*
- *Miami message list messages were expanded into 'verbose' mode on receipt in the aircraft*

CPDLC CRD


N60669
J-79 REQUEST LEVEL 350
0669 MAINTAIN FLIGHT LEVEL 410
J-79 UNABLE
0669 N60669 DATA LINK CHECK
J-79 ROGER
DL039 MAINTAIN FLIGHT LEVEL 310
NJ-79 WILCO
NJ-79 REQUEST LEVEL 310
0669 MAINTAIN FLIGHT LEVEL 350
J-79 ROGER
J-79 REQUEST LEVEL 350
0669 ROGER

Controller Displays

- *The controller displays were closely similar to DSR displays*
- *The display had to present radar and ADS positions separately despite differing update rates*
- *Data blocks were 'attached' to the most accurate position report*
- *The ADS position was shown using a small circle*
- *Radar positions were shown as a standard NAS 'slash'*
- *The flight data blocks used were standard NAS format but with other indicators for:*
  - *Logged on to data link not under the sector's control*
  - *Logged on to data link and under the sector's control*
- *Miami formats were not used as they would not be immediately self evident*

Data Block Formats

ABC123
370C
317 425

ABC123
370C
317 425

Current Miami format

EARL format

Integrated Display

- Rather than provide a series of separate components the VOIP, CPDLC and Display were integrated
- The intention was to reduce controller workload in handoff
- When the handing off controller ‘flashes’ the aircraft to the receiving controller, a CPDLC ‘Next Data Authority’ message is automatically triggered to the aircraft
- When the receiving controller assumes the aircraft
  - A ‘Current Data Authority’ message is triggered to the aircraft
  - The aircraft VOIP is transferred to the multicast group IP of the assuming controller
- The pilot or controller do not carry out any verbal exchange
- The lower communications levels of the data-link can immediately identify, and alert the pilot and controller to any failure of the link without any transmission being made
- This totally silent handoff could reduce controller workload in some sectors considerably and increase capacity
- The linked CPDLC messages ensure pilot situational awareness

Scenarios

- *The demonstration was intended to show the seamless transition from radar to ADS only domain*
- *The Gulf of Mexico was chosen as a suitable demonstration example as being able to route traffic out into the Gulf could considerably reduce pressure on the Southern US*
- *This is already done in a limited way with the weather avoidance Q routes*
- *Houston Center set up an exercise area in the 'radar hole' in the Gulf that would allow the demonstration between 22:00 and 04:00 local*
- *The live aircraft was to fly from New Orleans out into the 'hole' where it would only be visible on ADS and reachable by SATCOM based VOIP*

Demonstration Flights

- *There were 3 demonstration flights*
- *The Connexion by Boeing aircraft took off from New Orleans – it could be seen taxiing on ADS with correct ground speed*
- *From then till it switched off ADS back on the ramp the aircraft was in continual surveillance coverage*
- *The normal Gulf of Mexico traffic was showing as live radar returns*
- *Traffic in the Gulf was greatly added to by simulated aircraft being 'flown' by pseudo-pilots at EARL Daytona Beach*
- *The simulated traffic was flying:*
  - *East West between Cypress in Florida and San Antonio, Texas*
  - *North South climbing out of and descending into Cancun (considered one of the more awkward tracks to control)*

Houston Center Live Flight

Flights

- Each flight followed a detailed demonstration test script to ensure repeatability
- In each flight the live aircraft flew 4 circuits of the trials area:
  - 2 legs using Ku one with Boeing SIP and one with EARL VOIP
  - 2 legs using Iridium one with SIP and one with VOIP
- The aircraft was 'controlled' using both VOIP and CPDLC
- EARL 'Riddle' simulated aircraft were controlled into conflict and deconflicted
- During the flight step-on and controller precedence in VOIP were demonstrated
- On the final flight the aircraft was descended to 10,000 at the southern boundary of the exercise area, remaining in ADS and VOIP contact throughout

Live flight

Achievements

- *EARL successfully embedded live aircraft in the real time simulator*
- *The simulator was successfully distributed continent wide and into an aircraft flying in the simulation*
- *The real time displays in the aircraft were actually receiving full displays of DO-242 ADS – this was equivalent to TIS*
- *The demonstrations showed that VOIP, apart from being transmissible over satellite, has a far superior capability than VHF*
- *VOIP enhanced capabilities step-on prevention and controller precedence worked*
- *VOIP and CPDLC integration with the displays and silent handoff showed how controller and pilot workload could be significantly reduced*

Connotations and Consequences

- *VOIP can multiplex on one shared VDL frequency – frequency 'congestion' ceases to be a problem*
- *The analogue bridge approach could allow all voice communications users to be added to a VOIP multicast group*
- *In theory the VOIP party line capability can be distributed world-wide using the Iridium capabilities so an aircraft in the Pacific could be in the same group as one in Europe*
- *Operationally CPDLC has been restricted to hard coded message sets, it is easy to generate more flexible but controlled approaches to message sets*
- *The SDN will provide information input into SWIM, information available from ADS and DAP such as aircraft intent or trajectories should not be discarded by using legacy transmission standards*

Operational 'Consequences'

- ***What do the GCNSS results mean to operational ATM?***
  - ***It is possible to provide a full ATM service to cooperating aircraft anywhere in the world***
  - ***The service provider and the service receiver need not be geographically related***
  - ***Oceanic aircraft could receive a full en-route service with no need for special procedures or separations***
  - ***With normal en-route separation standards, all the current North Atlantic traffic could use NAT A***
  - ***The fuel and environmental pollution savings could be immense and allow the aircraft operators to carry more freight***
  - ***There are no new enablers required for this to happen GCNSS showed that all this was possible using existing capabilities***
- ***It will soon be necessary to*** defend ***maintenance of the legacy systems when it is technically feasible to improve them increasing capacity and maintaining safety***

QED ?

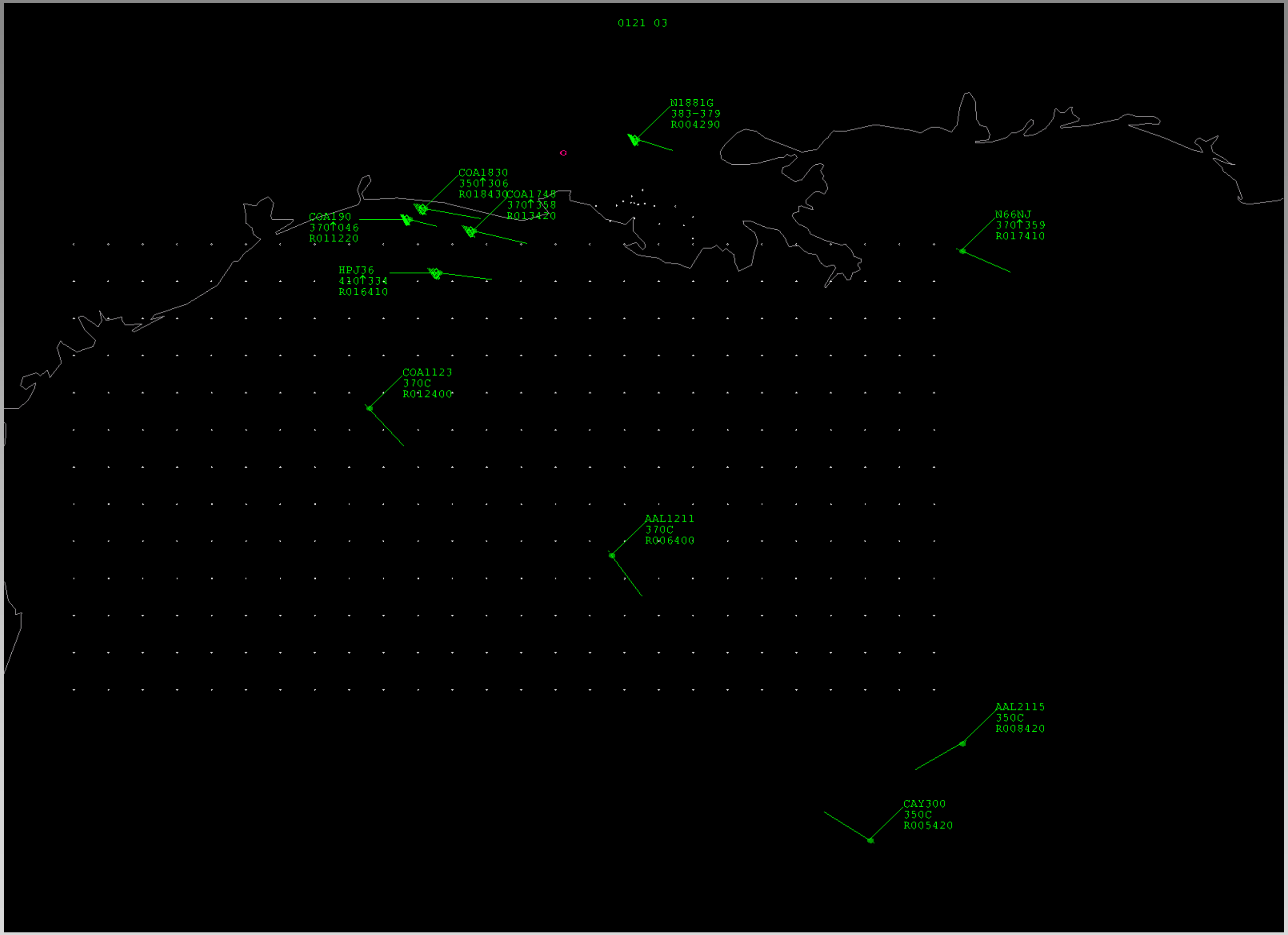
"GCNSS was to demonstrate that the current limitations of land based radar and VHF radio communications can be overcome by using existing satellite based technologies such as Ku and L band satellite communications and satellite based navigation using GPS; and that the investment that has already been made into these technologies can be leveraged to provide a truly Global solution to CNS/ATM problems without any new technological enablers being required".

This was successfully demonstrated by the FAA and Boeing team

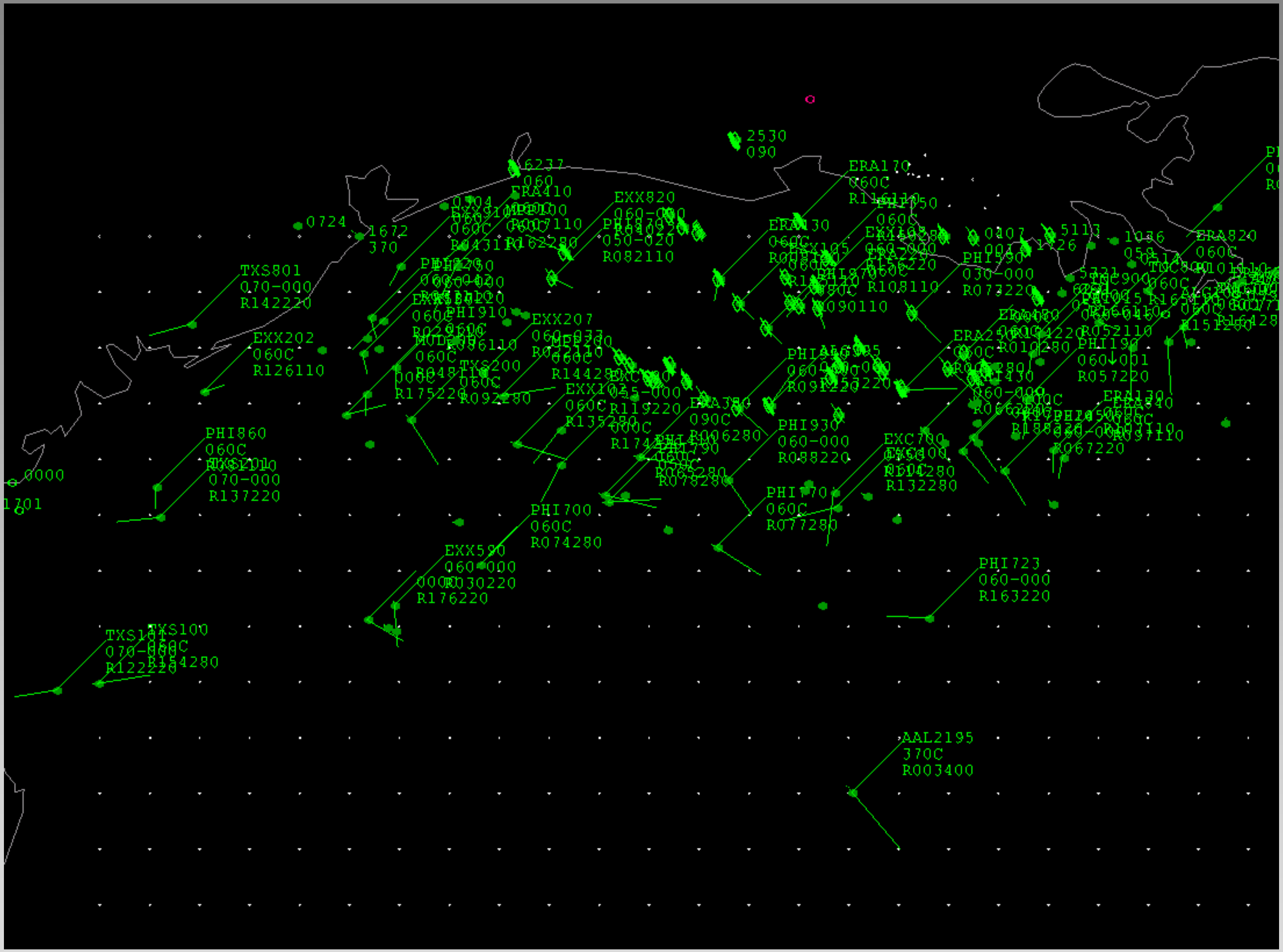
Conclusion

- *GCNSS was challenging for ERAU ATM Research Laboratory*
- *EARL real time simulator was upgraded to allow embedding of live radar and ADS surveillance positions*
- *The displays were upgraded to show both radar and ADS and CPDLC and VOIP were integrated with the display*
- *A simplified data block design was used to indicate the status of the aircraft*
- *VOIP was implemented with step on prevention and controller precedence*
- *The LAN based simulator was then distributed country wide and into a live aircraft*
- *The live demonstrations showed seamless transition between radar and ADS domains and high quality communications*
- *The live aircraft was visible and in communications at all times including 10,000 feet in the center of the Gulf of Mexico and while taxiing at New Orleans airport*
- *It would be possible to provide the same ATC service anywhere in the world using the same existing technology from anywhere else in the world*

ADS and Radar Display



Helicopter GOMEX Simulation



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